AD/A-003 241

TERMINAL HOMING ENGINEERING FLIGHT TEST T7 AND MT7 MISSILE LAUNCH TRANSIENTS DATA REDUCTION AND SUMMARY

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Missile Tipoff Transients
Vibration

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

The launch transients at tipoff for forty-six T7 and MT7 missile launches are compiled, grouped according to Quadrant Elevation Angle, and the mean tipoff transients and standard deviations thereof are calculated. Results are discussed generally in terms of launch rail rigidity, wind velocity components, and rail/shoe dynamics.

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19. (Cont'd)
Launch Azimuth Offsets
Tower Launched
Ground Launched
Helicopter Launched
Terminal Homing Accuracy Demonstration

CONTENTS

ILLUSTRATIONS

TABLES

1.0 GENERAL

The purpose of this report is to compile, and where possible, group and quantify statistically the attitude tip-off transients in terms of launch conditions for all T7 and MT7 missiles launched under the auspices of the THAD flight test program between 29 March 1971 and 8 May 1974. Launch conditions for each missile have been compiled in Table 1. The rationale for selecting the launch conditions included in Table 1 was based upon the premise that up to and including the time at which tip-off occurs (i.e., when the aft guide shoe exits the launch rail), the initial attitude rates are affected by only the following:

- Launcher Rigidity
- Rail/Shoe Dynamics and Helicopter Vibrations
- Longitudinal and Transverse Wind Velocity Components
- Launch Mode and Altitude.

2.0 ATTITUDE RATES DETERMINATION

Attitude rates in pitch, yaw, and roll planes at tip-off time were determined from flight test oscillograph records. The first one/half second (referenced to rocket motor ignition) of the missile pitch rate, yaw rate, and roll displacement have been reproduced by tracing the flight records, and are included as the graphical section of this report (see Appendix A, Figure A-1). Pitch and yaw rates and roll displacement can be scaled directly from the reproductions with reasonable accuracy, since the calibration ranges for each measurement are tick marked at 10 degrees per second intervals. Roll rate can be obtained simply by measuring the slope of a line drawn tangent to the roll displacement trace at the time of interest.

3.0 ATTITUDE RATES DISCUSSION

Figure 1 typifies the shape of the pitch rate trace for all launches except missiles 001 and 002, for ignition < time $\lesssim$ 0.14 seconds.

The segment of the trace from 0 to 3 is the pitch rate history while both guide shoes are in sliding contact with the launch rail. The initial pitch rate perturbations, 1 and 2 , are induced by thruster and guide shoe misalignment tolerances generating dynamical force reactions as the shoes ride on the constraining rail. At point 3 , the leading shoe exits the launch rail causing an instantaneous downward moment in the pitch plane about the trailing shoe. The trailing shoe separates from the launch rail at point 4 , and missile attitude control becomes exclusively a product of autopilot command.

TABLE 1

TABULATION OF T7 AND MT7 MISSILE LAUNCH CONDITIONS

MISSILE S/N	LAUNCH MODE	LAUNCH PLATFORM	PLATFORM VELOCITY (KNOTS)	PLATFORM ALTITUDE (METERS)	SURFACE WINDS * FROM T. NORTH / VELOCITY (KNOTS)	RESULTANT CE (DEGREES)	REMARKS
001	Direct	Tower	0	10.6 AGL	360/09	8	
002	Direct	Tower	0	10.6 AGL	270/14	5	
003	Direct	Tower	0	10.6 AGL	280/10	8	
004	Indirect	Ground Launcher	0	1.0 AGL	015/08	45	Wide FOV (40°) Seeker.
005	Direct	Tower	0	10.6 AGL	315/08	8	
006	Direct	Tower	0	10.6 AGL	360/07	8	
007	Direct	Tower	0	10.6 AGL	180/14	8	
008	Direct	UH-1C	80	207.3 AGL	018/06	-3	
009	Direct	Tower	0	10.6 AGL	150/07	8	
010	Direct	UH-1C	80	213.1 AGL	100/08	-3	
011	Direct	UH-1C	80	193.6 AGL	180/08	-3	
012	Direct	UH-1C	80	200.0 AGL	330/10	-3	
013	Direct	UH-1C	80	151.2 AGL	180/05	-3	Target moving North to South at 17.3 knots.
014	Direct	UH-1C	80	182.9 AGL	115/06	-3	Night Firing with narrow (5°) FOV Seeker.
015	Direct	Tower	0	10.6 AGL	180/10	8	Wide (40°) FOV Seeker.
016	-	-	-	-	-	-	No telemetry data taken.
017	Direct	UH-1C	80	214.9 AGL	170/13	-3	
018	Direct	UH-1C	7 (Vertical)	27.4 AGL	030/14	4	Narrow (5°) Field-of-View.
019	Direct	UH-1C	80	77.7 AGL	240/03	1	Target moving North to South at 34.5 knots. Narrow (5°) Field-of-View Seeker.

TABLE 1 (Continued)

TABULATION OF T7 AND MT7 MISSILE LAUNCH CONDITIONS

MISSILE S/N	LAUNCH MODE	LAUNCH PLATFORM	PLATFORM VELOCITY (KNOTS)	PLATFORM ALTITUDE (METERS)	SURFACE WINDS FROM T. NORTH / VELOCITY (KNOTS)	RESULTANT QE (DEGREES)	REMARKS
020	Direct	UH-1C	80	157.3 AGL	360/09	-3	Missile fired with UH-1C Long. axis. 14° CCW from launcher/target LOS.
021	Direct	UH-1C	80	152.7 AGL	360/18	-3	Narrow (5°) FOV. Tank target crossing at 24 knots.
022	Direct	UH-1C	80	243.9 AGL	215/14	-3	
023	Direct	UH-1C	80	180.2 AGL	210/21	-3	Wide (40°) FOV Seeker. Target moving North to South at 21.8 knots.
024	Direct	AH-1G	135	223.8 AGL	293/21	-3	Wide FOV Seeker masked to 12° X 17° FOV.
025	Direct	UH-1C	80	185.4	150/03	-3	
026	-	-	-	-	-	-	Launcher Qual. No T/M data.
028	Indirect	Ground Launcher	0	1.0	170/03	45	Olive-drab covering on target to decrease reflected laser energy.
029	Direct	AH-1G	135	192.1	204/05	-3	Airborne laser; wide FOV masked to 12° X 17°.
030	Indirect	Ground Launcher	0	1.0	349/07	45	
031	Indirect	Ground Launcher	0	1.0	210/15	45	
032	Indirect	Ground Launcher	0	1.0	030/06	45	
035	Aeroballistic	UH-1C	70	182.9	200/17	-1	3 Shoes.
051	Direct	AH-1G	131	182.9	200/16	0	Ripple Fire Test with Missile S/N 050.
052	Direct	AH-1G	130	157.9	110/09	-2	
054	Direct	AH-1G	130	148.8	200/17	-3	
056	Direct	AH-1G	120	182.9	360/11	0	Night Firing.
057	Direct	AH-1G	130	157.9	110/09	-2	Papid Fire Test with Missile S/N 052.

TABLE 1 (Continued)

TABULATION OF T7 AND MT7 MISSILE LAUNCH CONDITIONS

MISSILE S/N	LAUNCH MODE	LAUNCH PLATFORM	PLATFORM VELOCITY (KNOTS)	PLATFORM ALTITUDE (METERS)	SURFACE WINDS * FROM T. NORTH / VELOCITY (KNOTS)	RESULTANT QE (DEGREES)	REMARKS
058	Direct	AH-1G	130	135.1	214/11	-2	
059	Direct	AH-1G	130	160.7	140/09	-1	
062	Direct	AH-1G	124	170.1	360/15	0	
063	Direct	AH-1G	124	201.2	360/17	0	
064	Direct	AH-1G	116	193.6	320/22	0	Missile/target offset at launch was 13°
065	Direct	Ground Launcher	0	2.0	180/11	8	Mutual Interference and Accuracy Demonstration. MT7 fired from ground, THAD 6 from AH-1G.
066	Aeroballistic	Ground Launcher	0	1.0	210/17	46	
050	Direct	AH-1G	131	159.7	200/16	0	Ripple Fire Test with Missile S/N 051.

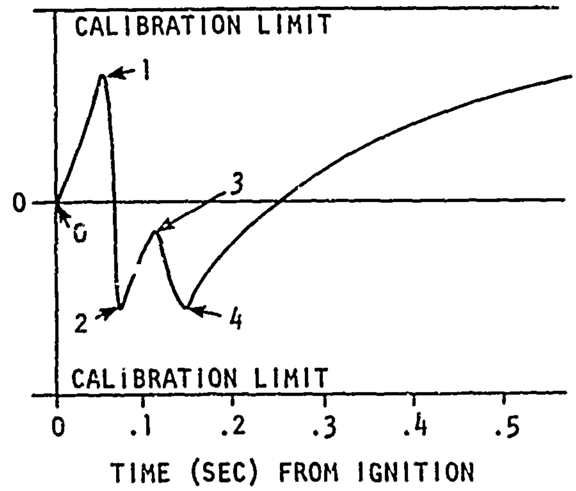


FIGURE 1. TYPICAL PITCH RATE TRANSIENT

The pitch rate traces for missiles 001 and 002 depart markedly in shape from Figure 1. This was caused by a less rigid launch rail support structure used for the initial two launches of the 7-inch missiles (see Figure 2). The structure was modified to achieve greater rigidity. Comparison of pitch rate traces during the initial one/half second interval for subsequent tower launches shows them to be generally of the same shape as launches from ground or helicopter. Figures 3 through 6 illustrate the various launch rail configurations used in T7 and MT7 firing tests. An attempt was made to assess the effect of surface wind velocity and direction on tip-off yaw rates. No meaningful pattern or correlation could be ascertained; therefore, it may be postulated that tip-off yaw motions and rates caused by crosswind components are small compared to those caused by rail/shoe dynamics. Launch altitude had no discernable effects on the attitude rate transients. However, launch azimuth offsets from the line-of-sight may have an effect on pitch and yaw rates. Missiles 020 and 064 were offset 14° and 13° respectively. The resulting pitch and yaw rates for these two firings differed significantly. However, launch Quadrant Elevation Angle and launch aircraft were different in each case; therefore an irrefutable causal relationship cannot be propounded.

4.0 RESULTS

Since relative wind velocity and resultant quadrant elevation angle (QE) are interrelated via helicopter flight characteristics, the missile flights were grouped according to QE and, where reasonable, the statistical mean and standard deviation for each group were calculated for pitch, yaw, and roll rates at tip-off. Tables 2, 3, and 4 show the results for QE angles of -3°, 8°, and 45° respectively. A

QE of -3° and 8° are synonomous with a direct fire launch mode, and a QE of 45° with an indirect launch mode. A comparison of Tables 2 and 3 suggests (1) helicopter vibrations prior to and during launch apparently do not affect attitude rates at tip-off. Further, helicopter launched missiles do not differ significantly from tower launches in pitch rate, and may even perform better in the yaw and roll planes. (2) Similarly, a comparison of Table 4 with Tables 2 and 3 suggests that the ground launcher configuration may represent the ideal launch bed with respect to rigidity. Also, with a QE of 45°, the rail/shoe interaction forces generated during launch are minimal. As can be deduced from the results of Table 4, this combination yielded the smallest values of tip-off attitude rates.

Missile 035 was modified to include a third launch shoe. The third shoe was added to reduce target jitter, as seen by the seeker head, during launch, and to reduce attitude rates at tip-off. Although the three shoed configuration resulted in moderate tip-off rates, a firm conclusion on the basis of a single test would be premature because some two shoed missiles exhibited smaller or larger tip-off rates.

Table 3 is interesting since it emphasizes the effect of launch rail rigidity. If all tower and ground launches at QE = 8°, except missile 001, are averaged and the standard deviation calculated for the remaining launches, the mean (expected) value for pitch rate increases to 21.570°/sec and the standard deviation decreases to 4.135°/sec. The tip-off pitch rate for missile 001 was 0°/sec, which suggests that an important difference existed between missile 001 and the rest of the family of tower launched missiles. This difference was the less rigid launch rail support structure used for the missile 001 firing test.

5.0 CONCLUSIONS

The following conclusions may be inferred based upon the statistical groupings of tip-off data and other flight data patterns for the T7 and MT7 flights considered in this report:

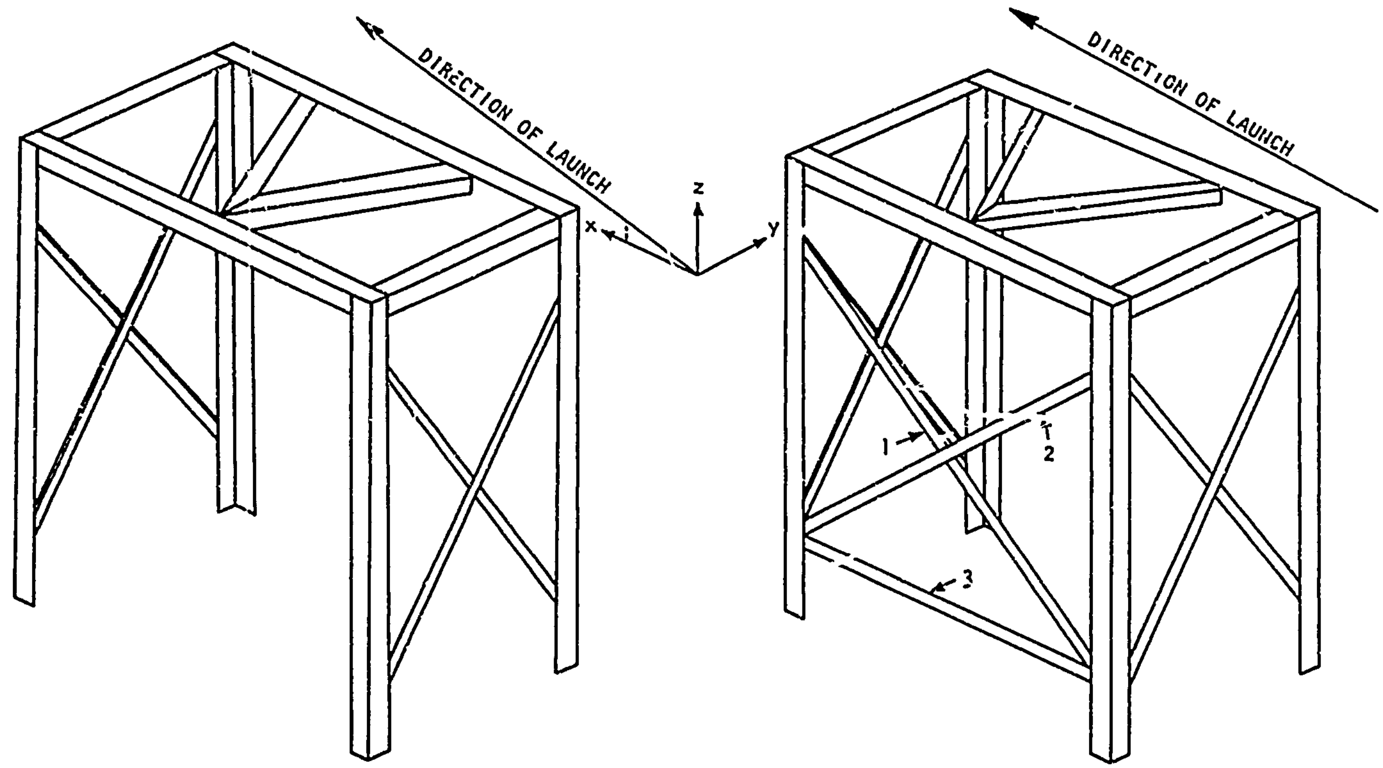
- Helicopter vibration, surface winds, and launch altitude are not important contributors to tip-off attitude rates for the T7 and MT7 missile. Indeed, in each attitude plane, the tip-off rates and the associated standard deviations are less for the helicopter launches than for the ground launches.

- Missiles fired from the ground launcher experienced significantly less mean attitude rates at tip-off than those fired from either tower or helicopter.

- The results of the statistical groupings of data presented in Tables 2, 3, and 4 imply that appropriate modifications to the launch rail support structure may result in very significant reduction of tip-off attitude rates.

6.0 RECOMMENDATIONS

To reduce the attitude rate transients at tip-off, attention should be directed towards the redesign or modification of the launch rail support and mounting structure with particular emphasis on the helicopter configuration. Such an effort should include accelerometer instrumentation of the present structure to record (via magnetic tape) the dynamical reactions of the structure during launch. Using these recordings as inputs to a vibrational shaker table, modifications to the launch rail support structure could be implemented and tested with no interruption of the current on-going missile firing test program.



(a)

LAUNCH RAIL SUPPORT STRUCTURE
FOR MISSILES 001 AND 002

(b)

MODIFIED LAUNCH RAIL SUPPORT STRUCTURE
MEMBERS 1, 2 AND 3 ADDED

FIGURE 2. LAUNCH RAIL SUPPORT STRUCTURES

FIGURE 3. TOWER LAUNCHER

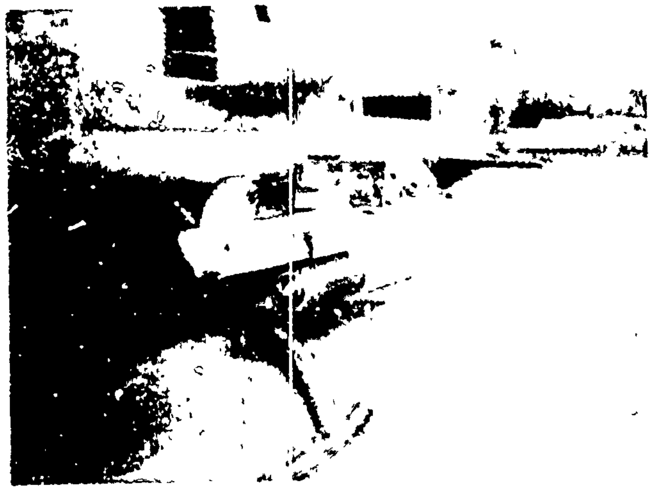


FIGURE 4. HELICOPTER LAUNCHER

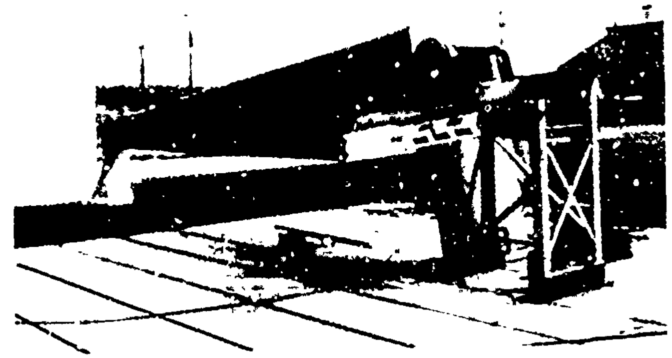


FIGURE 5. GROUND LAUNCHER

FIGURE 6. TOWED GROUND LAUNCHER

TABLE 2

ATTITUDE RATES ANALYSIS AT TIP-OFF FOR T7 AND MT7 MISSILES AT CONSTANT VALUES OF QE

HELICOPTER LAUNCHED AT QE = -3°

MISSILE NO.	HELICOPTER MODEL	TIP-OFF PITCH RATE, °/s	TIP-OFF YAW RATE, °/s	TIP-OFF ROLL RATE, °/s
008	UH-1C	22	0	59
010	UH-1C	21	-3	33
011	UH-1C	20	-4	13
012	UH-1C	19	3	68
013	UH-1C	21	2	67
014	UH-1C	19	0	36
017	UH-1C	17	-2	13
020	UH-1C	19	0	10
021	UH-1C	15	0	24
023	UH-1C	22	0	26
024	AH-1G	22	-2	10
025	UH-1C	18	0	49
029	AH-1G	15	0	24
054	AH-1G	30	1	16
		AVG. TIP-OFF PITCH RATE 20 °/s -STANDARD DEVIATION- 3.495 °/s	AVG. TIP-OFF YAW RATE -0.357 °/s -STANDARD DEVIATION- 1.797 °/s	AVG. TIP-OFF ROLL RATE 32 °/s -STANDARD DEVIATION- 20.117 °/s

TABLE 3

ATTITUDE RATES ANALYSIS AT TIP-OFF FOR T7 AND MT7 MISSILES AT CONSTANT VALUES OF QE

TOWER & GROUND LAUNCHED AT QE = 8°

MISSILE NO.	LAUNCHER TYPE	TIP-OFF PITCH RATE, °/s	TIP-OFF YAW RATE, °/s	TIP-OFF ROLL RATE, °/s
001	TOWER	0	-4	-65
003	TOWER	19	-23	-163
005	TOWER	25	-7	24
006	TOWER	14	15	-134
007	TOWER	27	-17	-107
009	TOWER	25	-25	-136
015	TOWER	20	-22	-72
065	GROUND	21	4	16
		AVG. TIP-OFF PITCH RATE 18.875 -STANDARD DEVIATION- 8.115	AVG. TIP-OFF YAW RATE -9.875 -STANDARD DEVIATION- 13.476	AVG. TIP-OFF ROLL RATE -79.625 -STANDARD DEVIATION- 65.182

TABLE 4

ATTITUDE RATES ANALYSIS AT TIP-OFF FOR T7 AND MT7 MISSILES AT CONSTANT VALUES OF QE

GROUND LAUNCHED AT QE = 45°

MISSILE NO.	LAUNCHER TYPE	TIP-OFF PITCH RATE, °/s	TIP-OFF YAW RATE, °/s	TIP-OFF ROLL RATE, °/s
004	GROUND	16	-11	25
028	GROUND	15	-18	-26
030	GROUND	2	9	35
031	GROUND	-6	5	18
032	GROUND	0	-4	-74
		AVG. TIP-OFF PITCH RATE 5.40 -STANDARD DEVIATION- 6.85	AVG. TIP-OFF YAW RATE -3.80 -STANDARD DEVIATION- 9.94	AVG. TIP-OFF ROLL RATE -11.60 -STANDARD DEVIATION- 38.12

APPENDIX

T7 AND MT7 LAUNCH TRANSIENT DATA - GRAPHICAL REPRESENTATION

Pitch rate, yaw rate, and roll angle data from ignition to + 0.5 sec for all T7 and MT7 test flights are contained in Figure A-1. Section 2.0 describes how these attitude rates were determined.

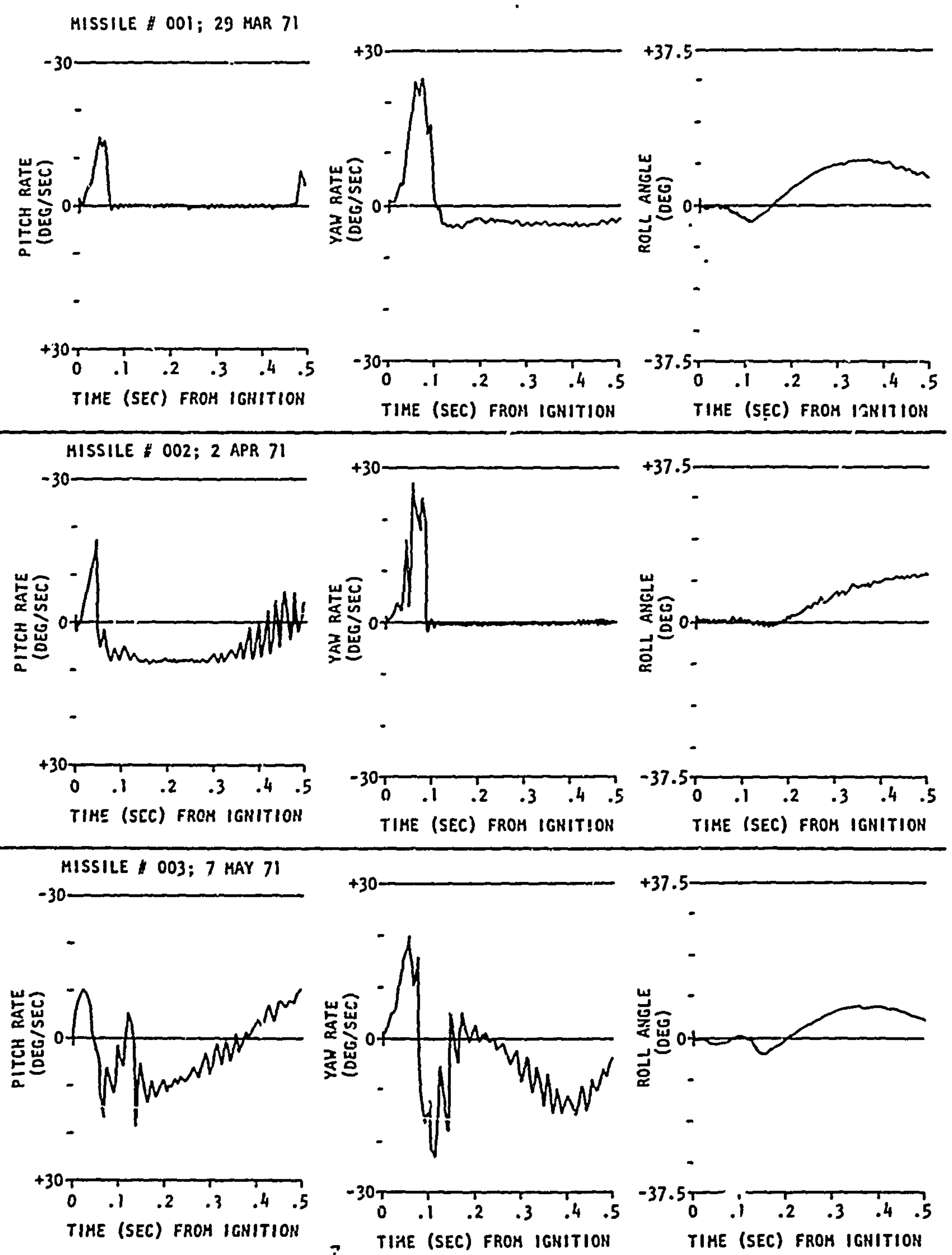


FIGURE A-1. T7 AND MT7 LAUNCH TRANSIENT DATA - GRAPHICAL REPRESENTATION

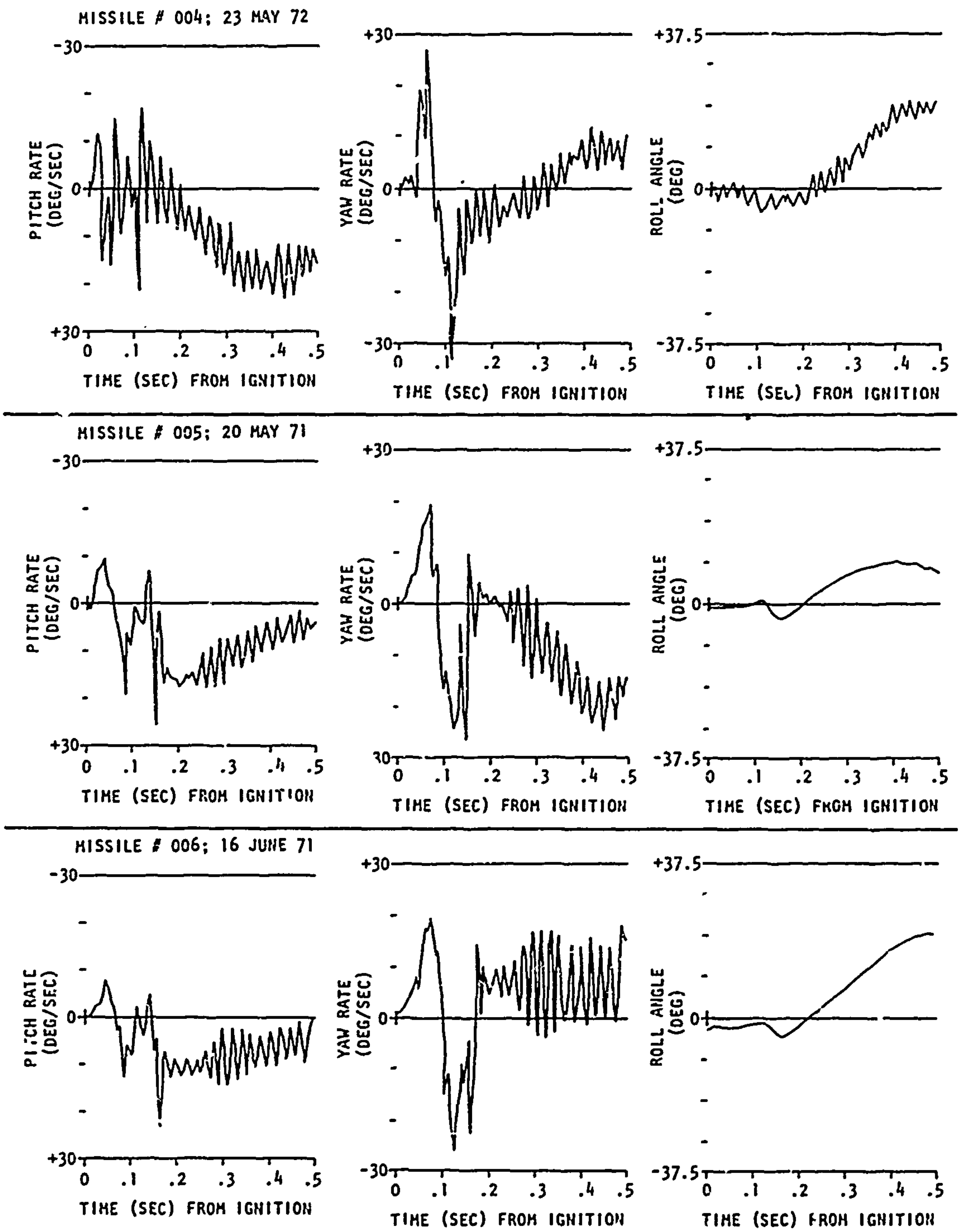


FIGURE A-1. T7 AND MT7 LAUNCH TRANSIENT DATA - GRAPHICAL REPRESENTATION (Continued)

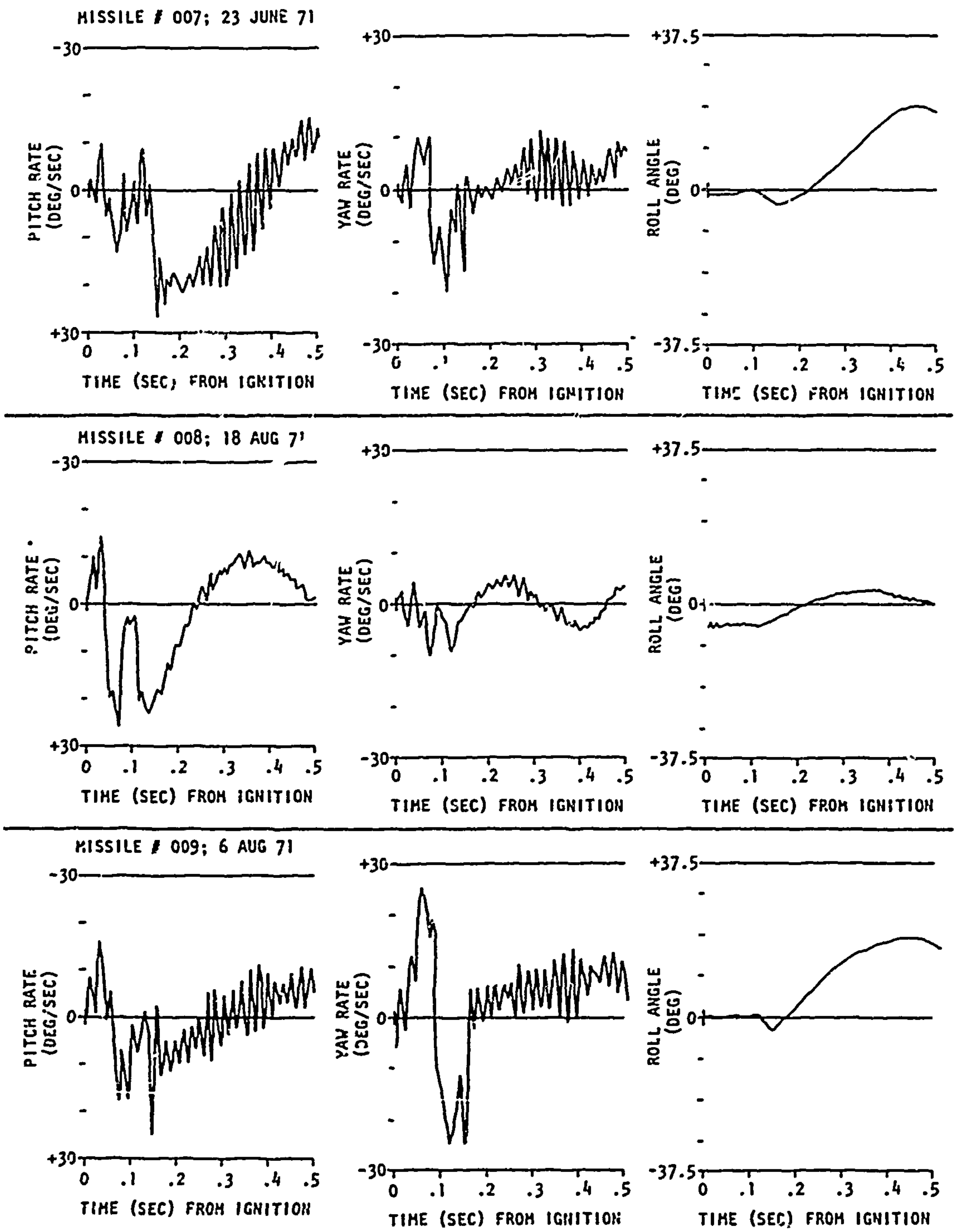


FIGURE A-1. T7 AND MT7 LAUNCH TRANSIENT DATA - GRAPHICAL REPRESENTATION (Continued)

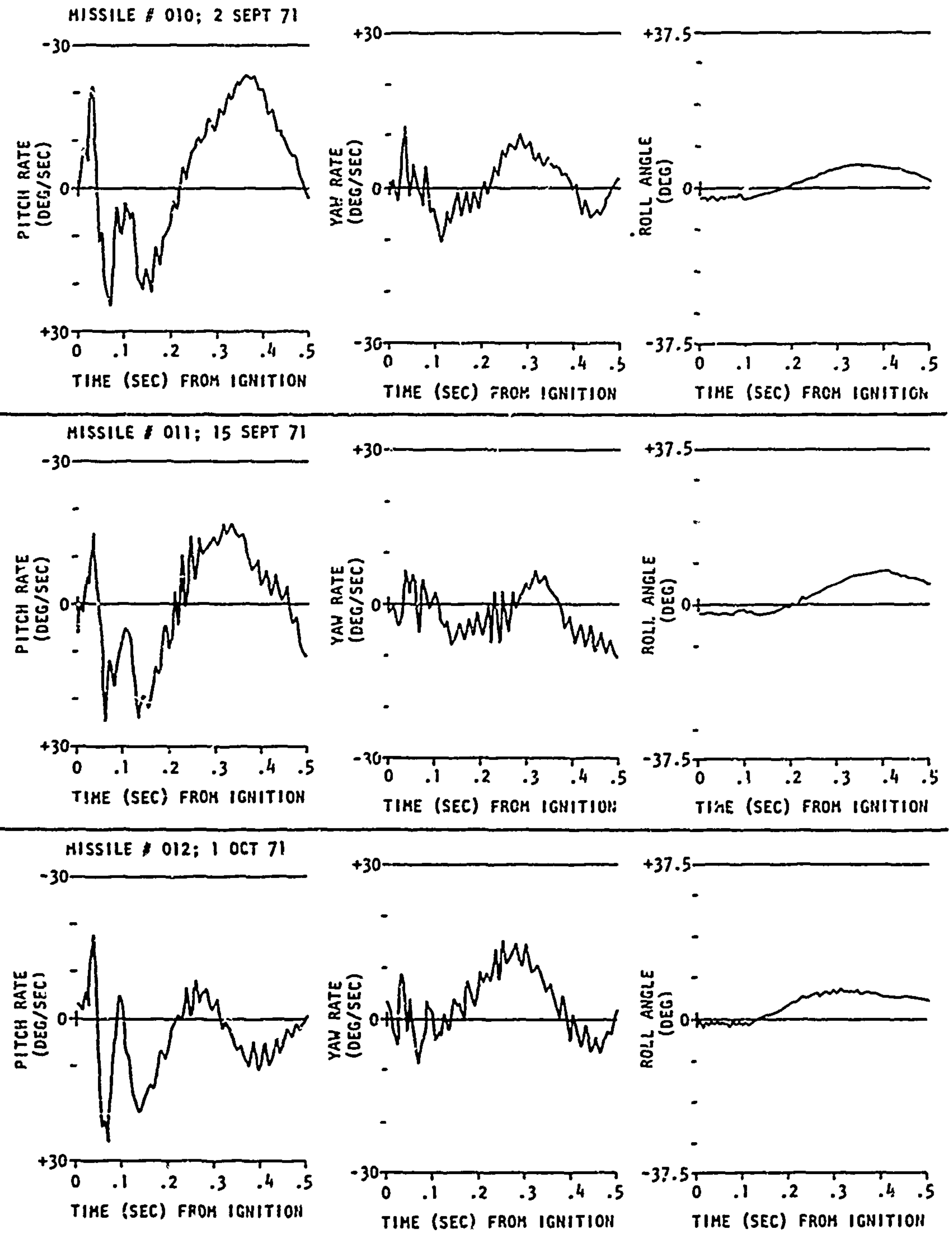


FIGURE A-1. T7 AND MT7 LAUNCH TRANSIENT DATA - GRAPHICAL REPRESENTATION (Continued)

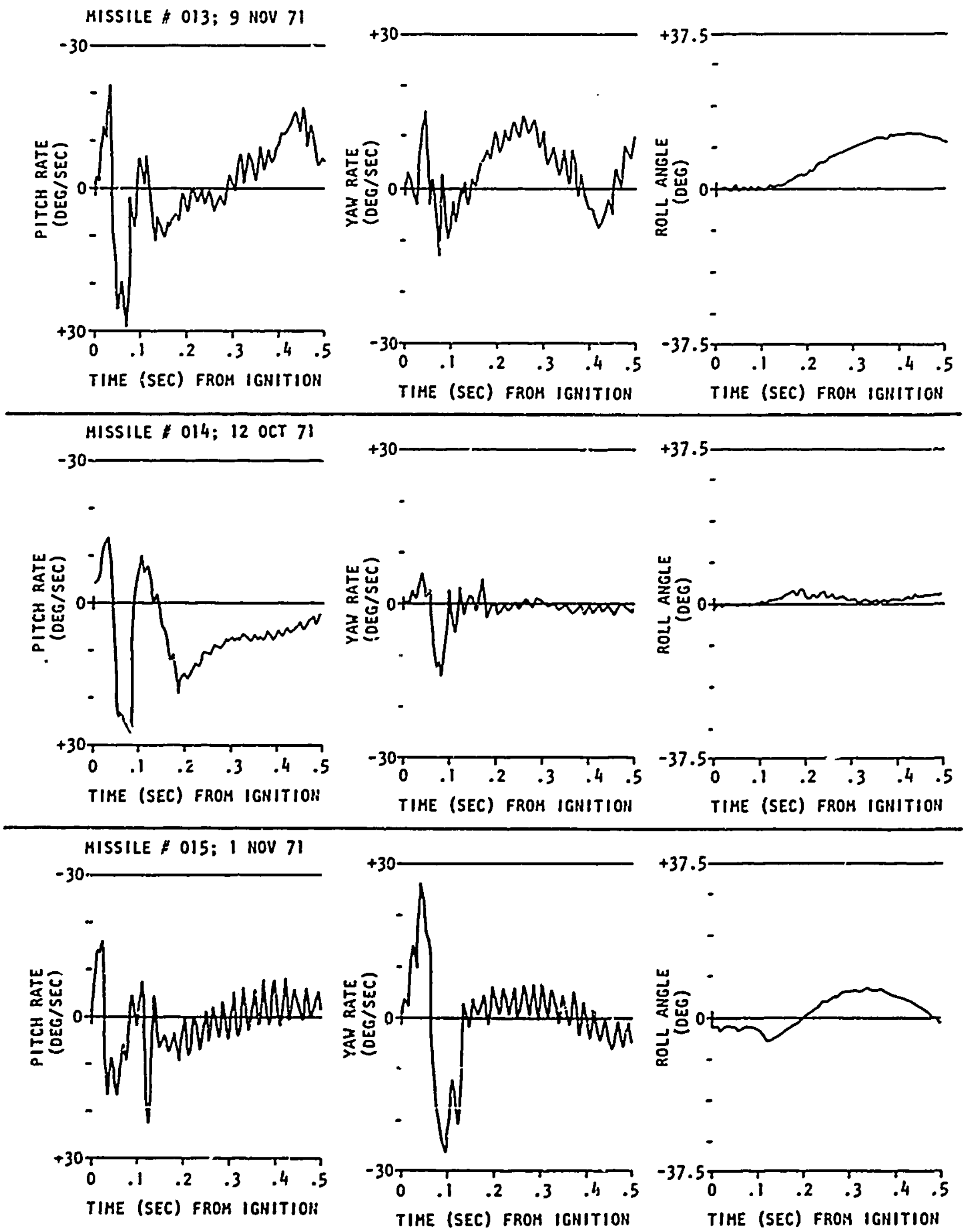


FIGURE A-1. T7 AND MT7 LAUNCH TRANSIENT DATA - GRAPHICAL REPRESENTATION (Continued)

MISSILE # 016; 24 JAN 74

NO TM DATA

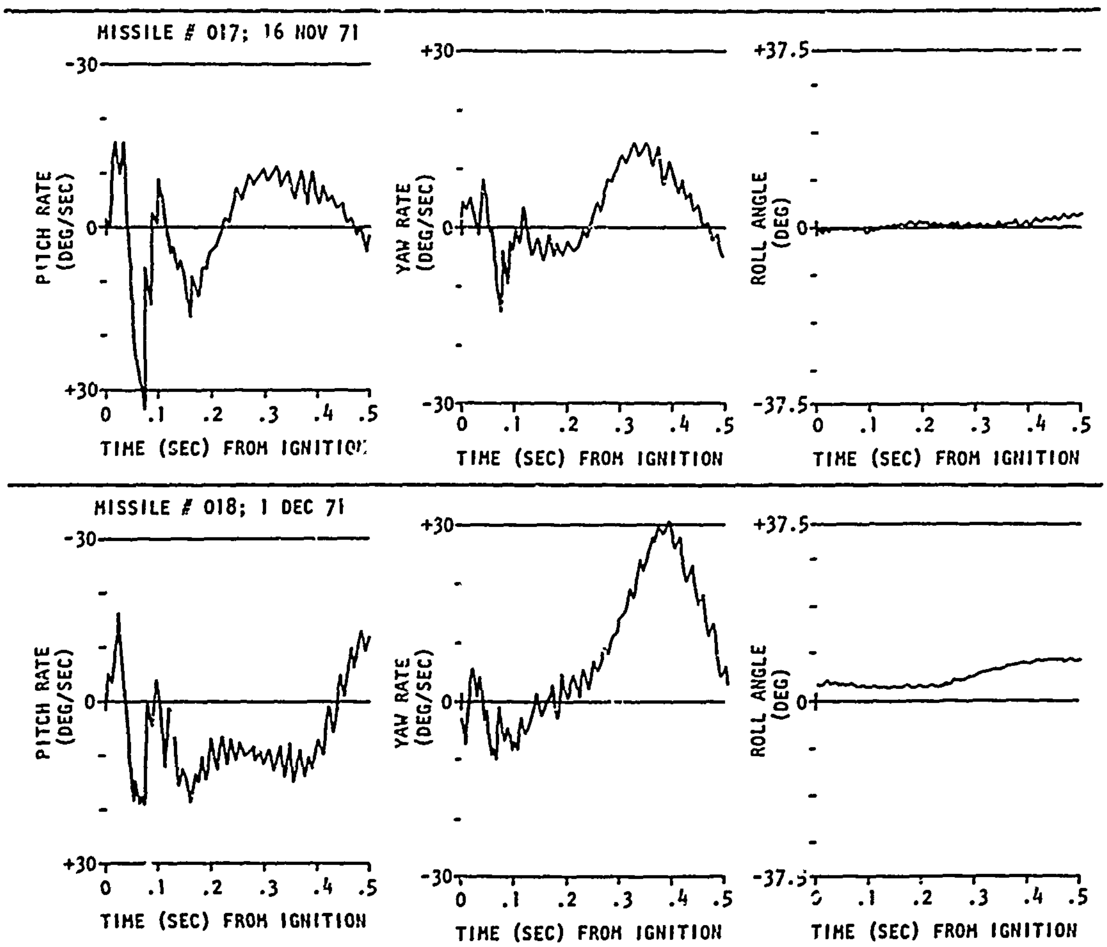


FIGURE A-1. T7 AND MT7 LAUNCH TRANSIENT DATA - GRAPHICAL REPRESENTATION (Continued)

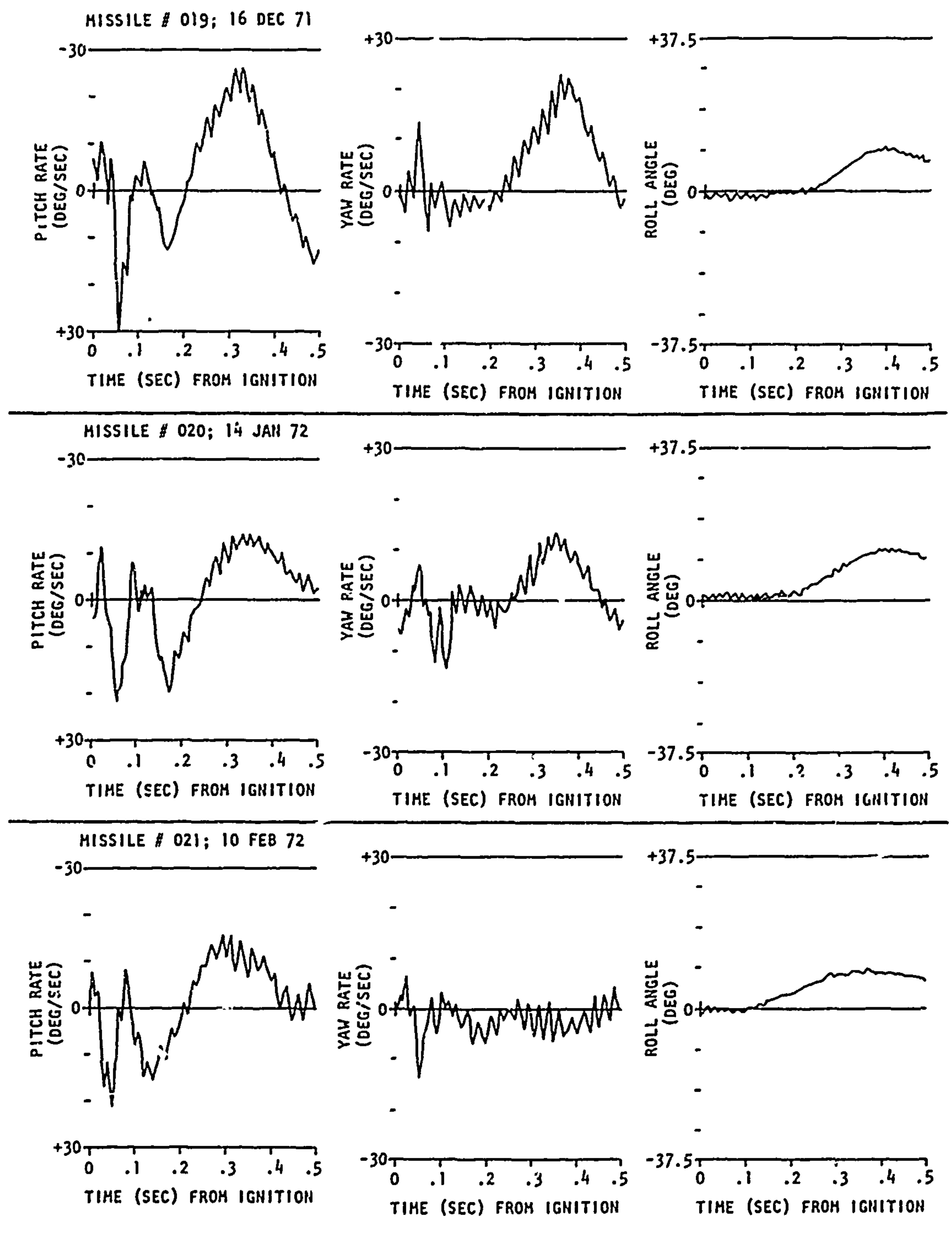


FIGURE A-1. T7 AND MT7 LAUNCH TRANSIENT DATA - GRAPHICAL REPRESENTATION (Continued)

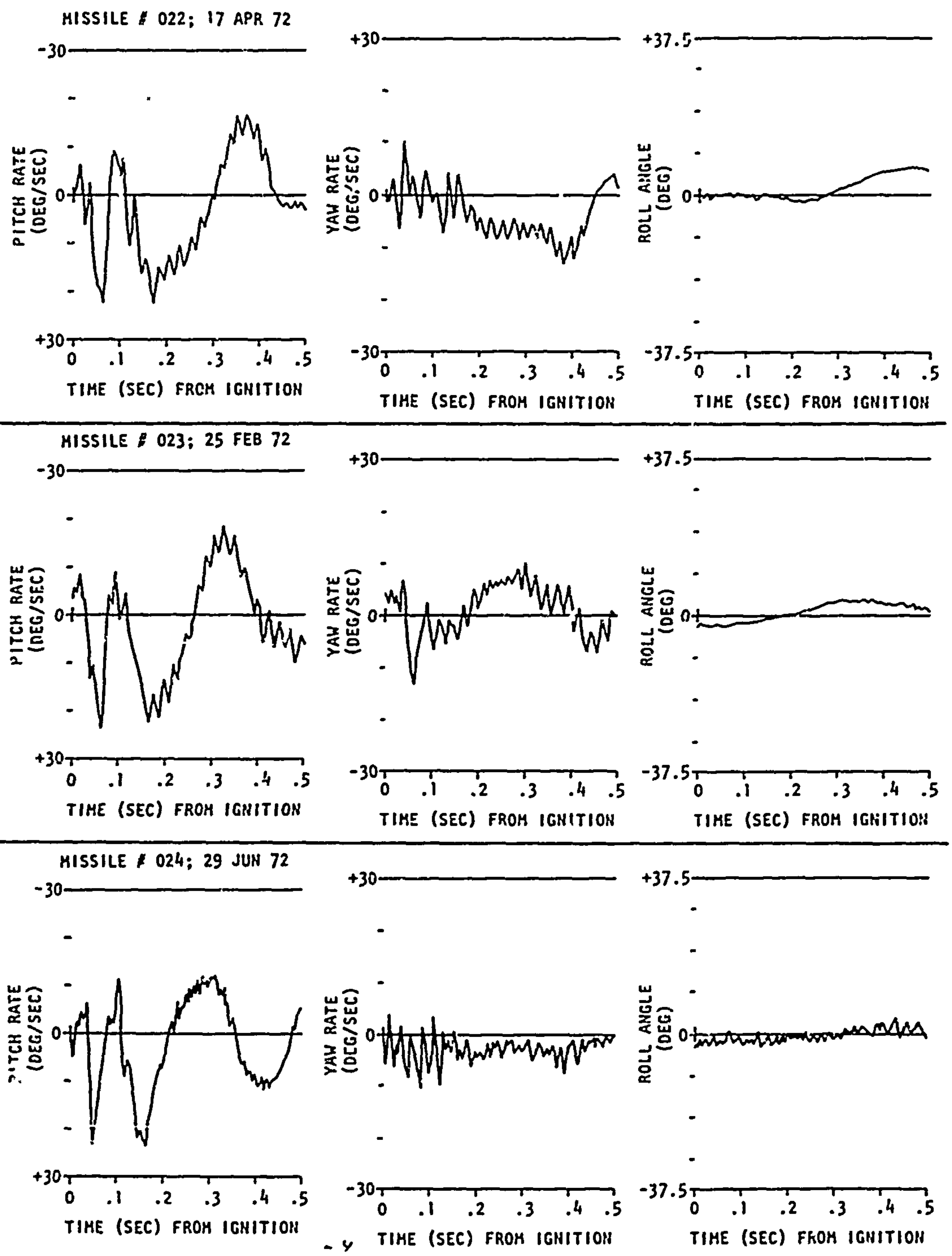
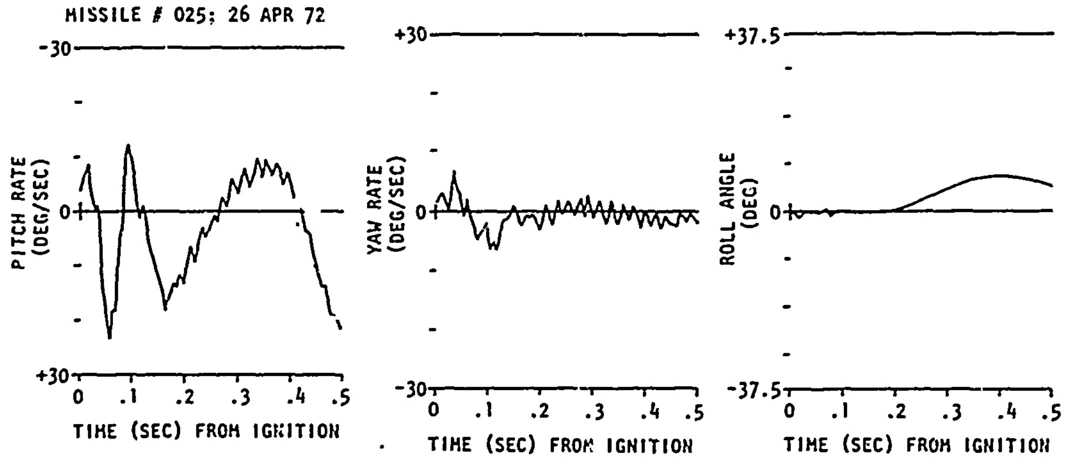


FIGURE A-1. T7 AND MT7 LAUNCH TRANSIENT DATA - GRAPHICAL REPRESENTATION (Continued)

MISSILE # 025; 26 APR 72



MISSILE # 026; 18 APR 73

LAUNCHER QUALIFICATION
NO T/M DATA

MISSILE # 028; 12 JUN 72

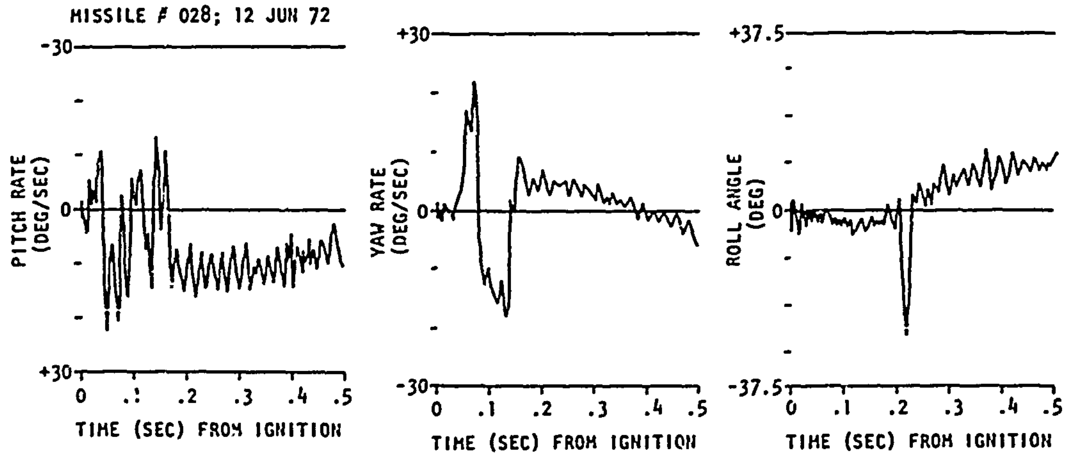


FIGURE A-1. T7 AND MT7 LAUNCH TRANSIENT DATA - GRAPHICAL REPRESENTATION (Continued)

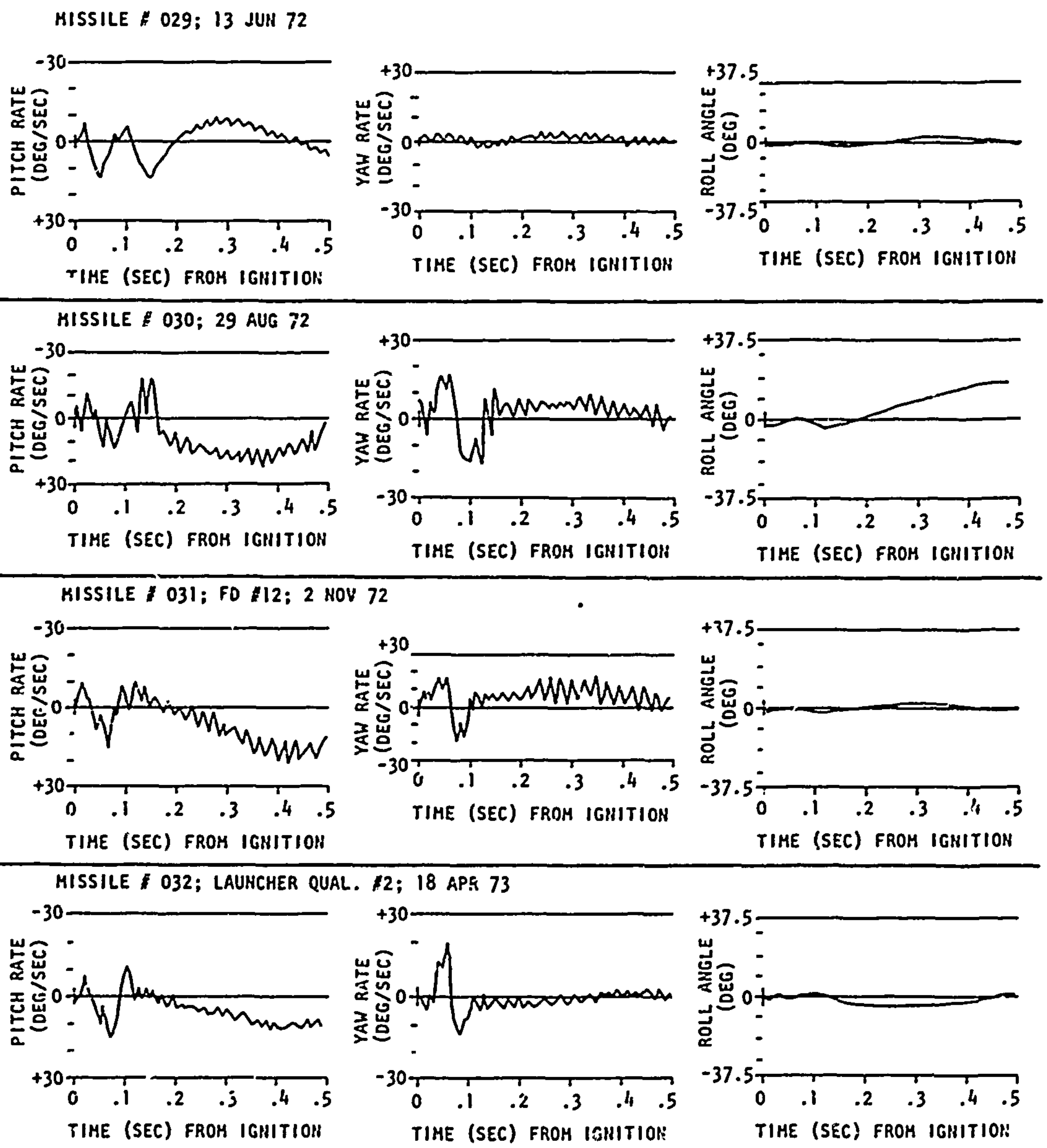


FIGURE A-1. T7 AND MT7 LAUNCH TRANSIENT DATA - GRAPHICAL REPRESENTATION (Continued)

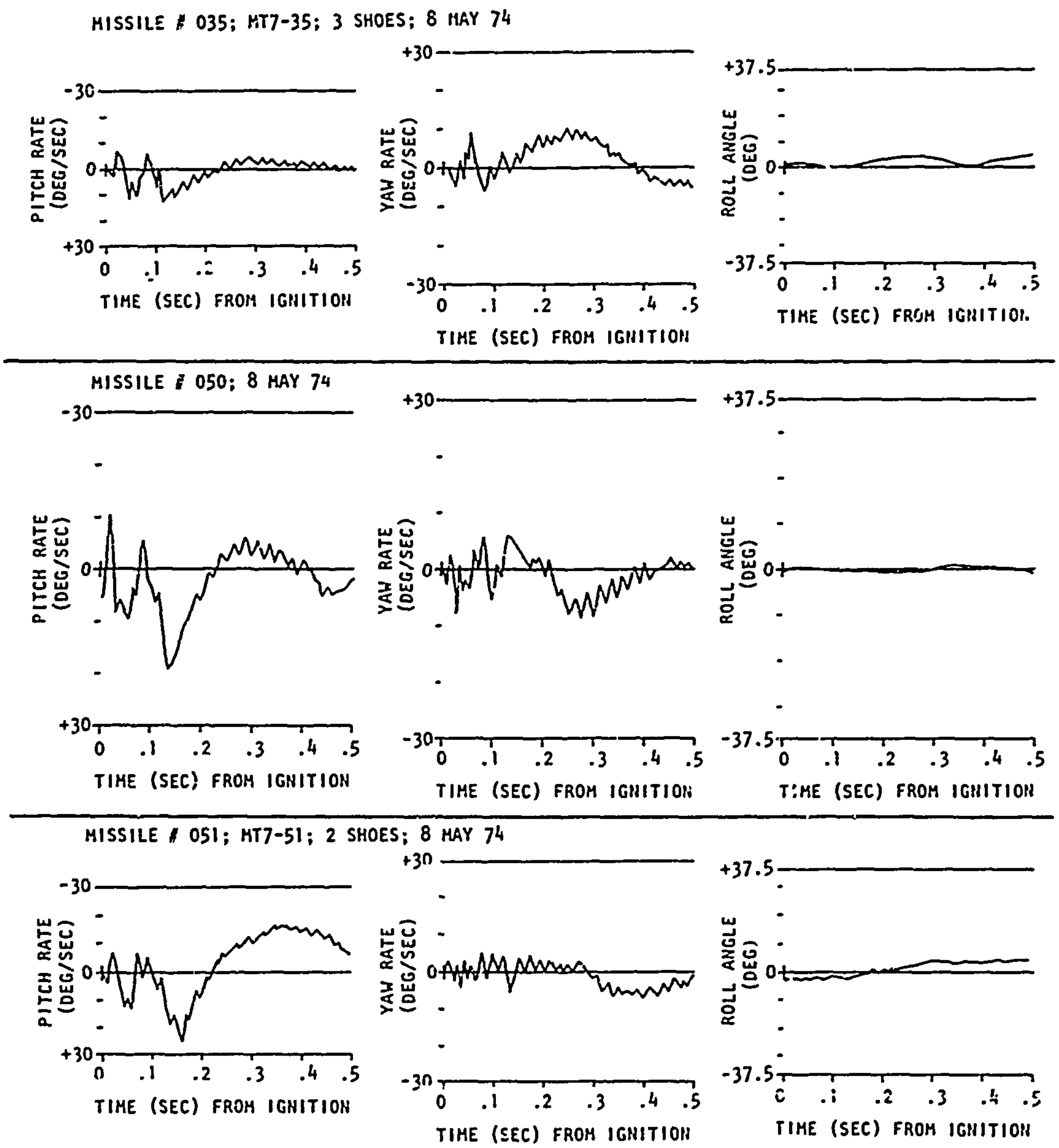


FIGURE A-1. T7 AND MT7 LAUNCH TRANSIENT DATA - GRAPHICAL REPRESENTATION (Continued)

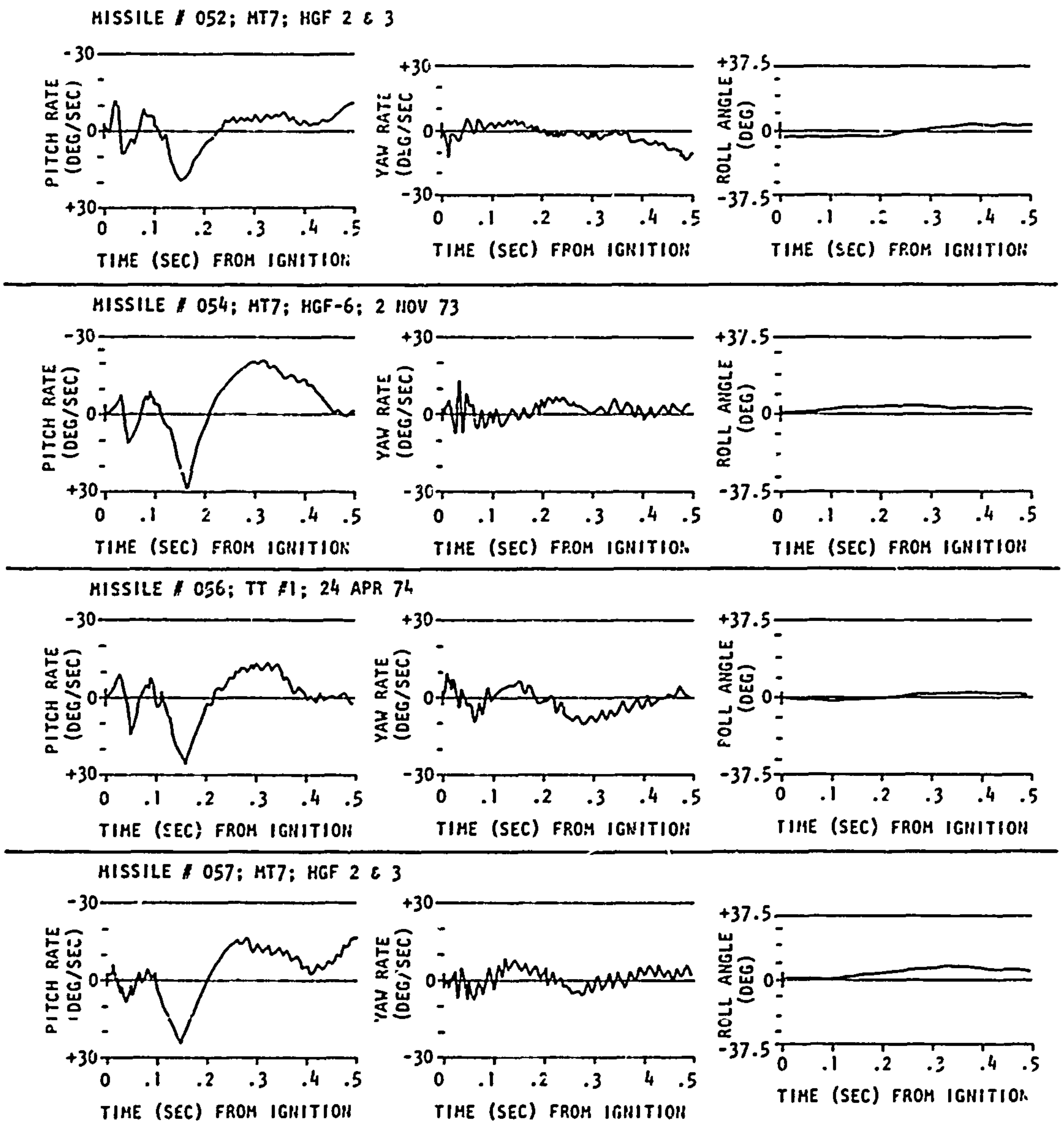


FIGURE A-1. T7 AND MT7 LAUNCH TRANSIENT DATA - GRAPHICAL REPRESENTATION (Continued)

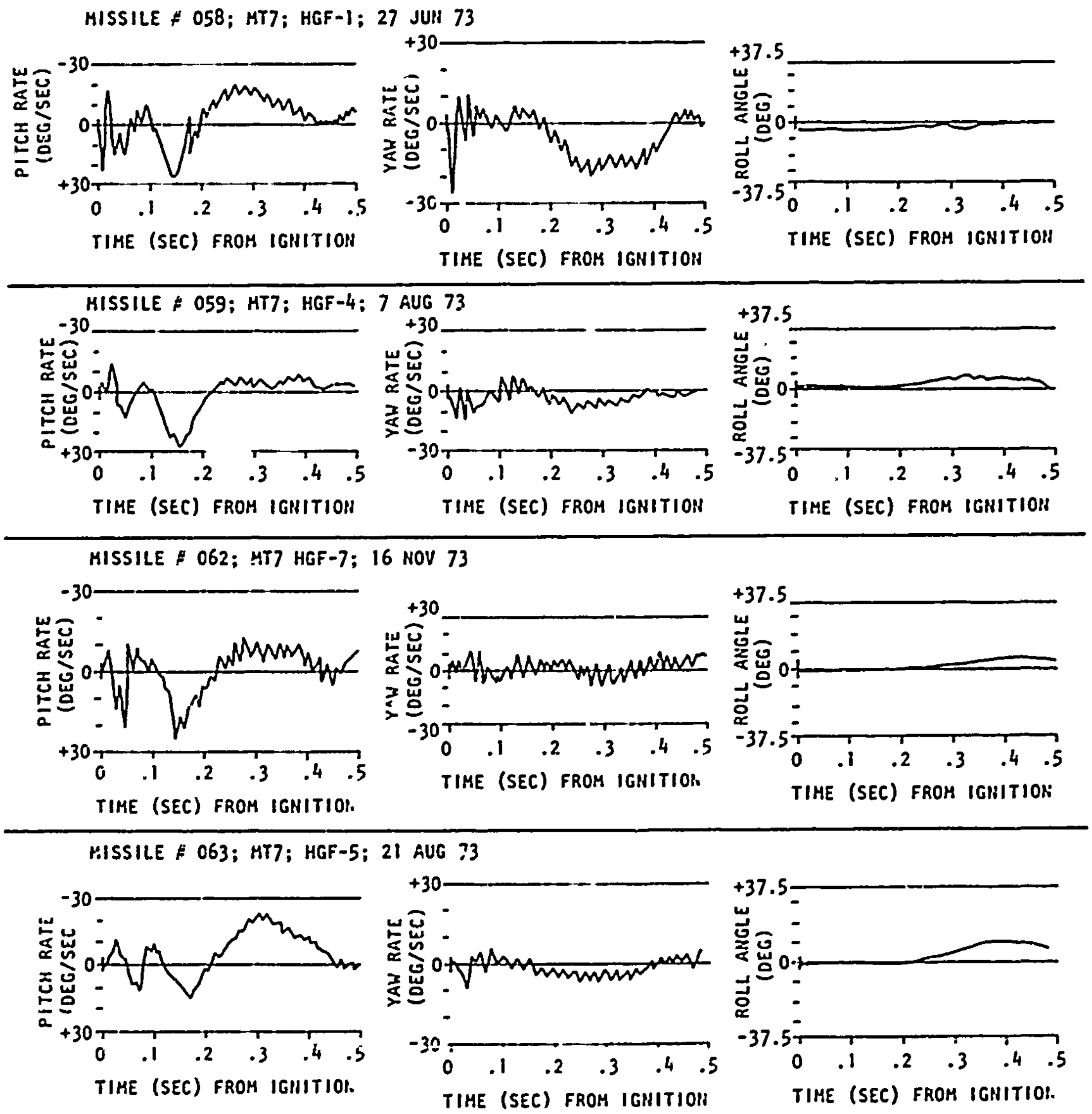


FIGURE A-1. T7 AND MT7 LAUNCH TRANSIENT DATA - GRAPHICAL REPRESENTATION (Continued)

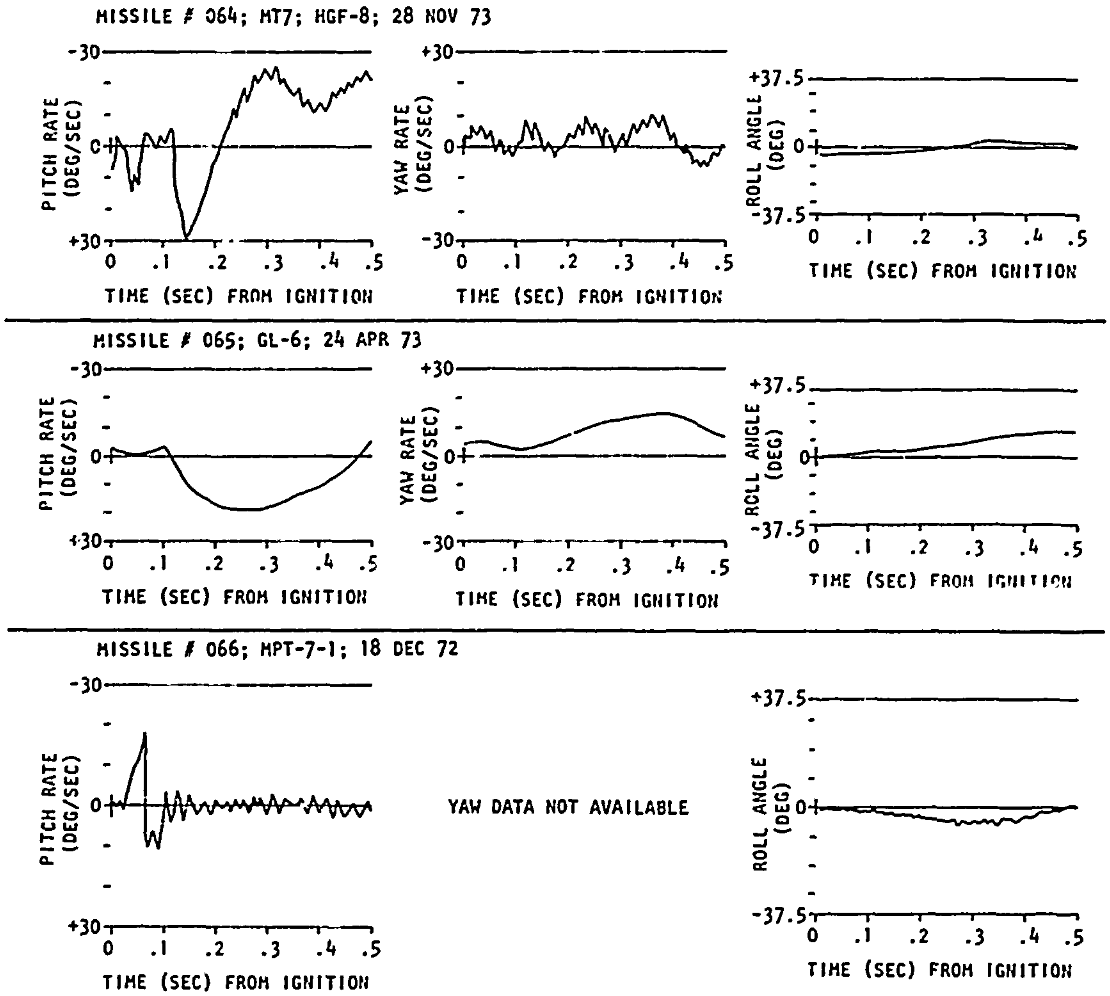


FIGURE A-1. T7 AND MT7 LAUNCH TRANSIENT DATA - GRAPHICAL REPRESENTATION (Continued)